CLAIMS

WHAT IS CLAIMED IS:

1. A downhole clock source, comprising:

a first crystal and a second crystal, wherein the first and second crystals are thermally coupled together;

an oscillator coupled to the first and second crystals, wherein the oscillator generates a first signal associated with the first crystal, and a second signal associated with the second crystal, each of the signals having a frequency; and

wherein the frequency of the first signal is more stable, with respect to a temperature of the crystals, than the frequency of the second signal.

2. The downhole clock source of claim 1, further comprising a temperature calculation circuit coupled to the oscillator, and wherein the temperature calculation circuit determines the temperature of the crystals based on a relationship between the frequency of the first signal and the frequency of the second signal.

3. The downhole clock source of claim 2, wherein the temperature calculation circuit further comprises a storage device, wherein a frequency behavior of the first and second signals with respect to temperature is stored in the storage device.

4. The downhole clock source of claim 3, wherein frequency behavior with respect to temperature is stored prior to deployment downhole.

5. The downhole clock source of claim 2, wherein the frequency of the first signal is temperature compensated according to the temperature of the crystals.

6. The downhole clock source of claim 5, further comprising a counter coupled to the first oscillator, wherein the counter may be adjusted using information from the storage device to produce a clock signal having a predetermined period regardless of temperature of the crystals.

7. The downhole clock source of claim 1, further comprising a heat sink coupled to the crystals.

8. The downhole clock source of claim 7, wherein the heat sink comprises a copper block.

9. The downhole clock source of claim 7, wherein the heat sink comprises a phase change material.

10. The downhole clock source of claim 9, wherein the phase change material is selected from a group consisting of sodium phosphate and barium hydro-oxide.

11. The downhole clock source of claim 9, wherein the phase change material includes a eutectic alloy.

12. The downhole clock source of claim 7, further comprising a temperature maintenance device coupled to the heat sink, wherein the temperature maintenance device is adapted to maintain temperature of the crystals within a range of temperatures.

13. The downhole clock source of claim 12, wherein temperature maintenance device is further adapted to maintain the temperature of the crystals in a range of temperatures where the first crystal exhibits substantially no frequency deviation as a function of temperature.

14. The downhole clock source of claim 7, further comprising a flask, and wherein the crystals and the heat sink are disposed within the flask.

15. The downhole clock source of claim 14, wherein the flask further comprises:

an outer liner;

an inner liner; and

wherein an inner portion of the inner liner defines a compartment within which the crystals and heat sink are disposed.

16. The downhole clock as defined in claim 15, wherein the inner and outer liner of the flask define a cavity between them.

17. The downhole clock source of claim 16, wherein the cavity is under a vacuum.

18. The downhole clock source of claim 15, wherein the heat sink a phase change material selected from a group consisting of sodium phosphate and barium hydro-oxide.

19. The downhole clock source of claim 18, wherein the phase change material includes a eutectic alloy.

20. The downhole clock source of claim 18, wherein the frequency of the first signal is substantially stable over a range of temperatures, and wherein the predetermined temperature of the material in the cavity is within the range of temperatures.

21. The downhole clock source of claim 1, further comprising an error detector circuit coupled to the oscillator, and wherein the error detector is adapted to determine a relationship between the frequencies of the first and second signals.

22. The downhole clock source of claim 21, wherein the error detector further comprises:

a first and a second counter each coupled to the oscillator, and wherein the first counter maintains a first count value proportional to the frequency of the first signal, and the second counter maintains a second count value proportional to the frequency of the second signal; and

a divider circuit coupled to the counters, and wherein the divider provides a ratio of the first counter value to the second counter value.

23. The downhole clock source of claim 22, wherein the ratio indicates the temperature of the crystals.

24. The downhole clock source of claim 21, wherein the error detector further comprises an up/down counter coupled to the oscillator, wherein the counter includes a count value that is proportional to a difference in frequency of the first and second signals.

25. The downhole clock source of claim 24, wherein the first signal increments the count value and the second signal decrements the count value.

26. The downhole clock source of claim 24, wherein the count value is indicative of the temperatures of the crystals.

27. The downhole clock source of claim 26, wherein the count value is substantially zero if the frequency of the first signal is substantially equal to the frequency of the second signal.

28. The downhole clock source of claim 21, further comprising:

a storage device coupled to the error detector;

a temperature maintenance device mechanically coupled to the crystals, and electrically coupled to the storage device, wherein the temperature maintenance device maintains the crystals within a predetermined temperature range; and

wherein the storage device contains a table relating the relationship between the frequencies of the first and second signals to a temperature of the crystals.

29. The downhole clock source of claim 21, wherein the error detector further comprises:

a mixer coupled to the oscillator;

a filter coupled to the mixer;

a spectrum analyzer coupled to the filter; and

wherein the mixer produces a mixed version of the frequencies associated with the first and second crystals to the filter;

wherein the filter provides the difference between the frequencies associated with the first and second crystals to the spectrum analyzer; and

wherein the spectrum analyzer provides spectral content information to a storage device.

30. The downhole clock source of claim 29, wherein the spectral content information indicates the temperature of the crystals.

31. The downhole clock source of claim 30, further comprising:

a storage device;

a temperature maintenance device mechanically coupled to the crystals, and electrically coupled to the storage device, and wherein them temperature maintenance device maintains the crystals within a predetermined temperature range;

wherein the storage device contains a table relating the spectral content information to a temperature of the crystals.

32. A method comprising:

thermally coupling a first crystal and a second crystal;

generating a first signal based on a frequency of oscillation of the first crystal;

generating a second signal based on a frequency of oscillation of the second crystal; and

wherein the first signal's frequency is more stable, with respect to temperature, than the second signal's frequency.

33. The method of claim 32, further comprising determining a temperature of the first and second crystals based on a relationship between a frequency behavior of the first crystal with respect to temperature, and a frequency behavior of the second crystal with respect to temperature.

34. The method of claim 33, further comprising storing an indication of the frequency behavior of the first and second crystals with respect to temperature in a storage device.

35. The method of claim 34, wherein the storing occurs prior to deployment downhole.

36. The method of claim 33, further comprising compensating the first signal's frequency according to the temperature of the crystals.

37. The method of claim 33, wherein thermally coupling the crystals further comprises coupling a heat sink to the crystals.

38. The method of claim 33, further comprising maintaining the temperature of the crystals within a range of predetermined temperatures.

39. The method of claim 38, wherein maintaining the temperature of the crystals further comprises maintaining the temperature of the crystals within a range of temperatures over which the first signal's frequency is substantially stable with respect to temperature.

40. The method of claim 33, further comprising:

maintaining a first count value proportional to the first signal's frequency;

maintaining a first count value proportional to the second signal's frequency;

calculating a ratio of the first and second count value, wherein the ratio of the first and second count values is proportional to the temperature of the crystals.

41. The method of claim 33, further comprising:

maintaining a count value;

incrementing the count value proportional to the first signal's frequency;

decrementing the count value proportional to the second signal's frequency; and

wherein the count value is proportional to the temperature of the crystals.

42. The method of claim 33, further comprising:
maintaining a count value;
decrementing the count value proportional to the first signal's frequency;
incrementing the count value proportional to the second signal's frequency; and
wherein the count value is proportional to the temperature of the crystals.

43. The method as defined in claim 33, further comprising:
mixing the first and second signal to produce a sum signal and a difference signal;
filtering out the sum signal;
analyzing, spectrally, the difference signal; and
wherein the spectral content of the difference signal is proportional to the temperature of the crystals.

44. A downhole tool, comprising:
a tool body; and
a clock source coupled within the tool body, the clock source comprising:
a first crystal and a second crystal thermally coupled together;
an oscillator coupled to said first and second crystals, wherein the oscillator generates a first signal having a frequency based on a frequency of oscillation of the first crystal, and a second signal having a frequency based on a frequency of oscillation of the second crystal, and wherein the frequency of oscillation of the first crystal is more stable, with respect to temperature, than the frequency of oscillation of the second crystal; and
a temperature calculation circuit coupled to the oscillator, and wherein the temperature calculation circuit uses a relationship between the first signal's frequency and the second signal's frequency to calculate a temperature of the crystals.

45. The downhole tool of claim 44, wherein the clock source is adapted temperature compensate the first signal's frequency according to the temperature of the crystals.

46. The downhole tool of claim 44, wherein the temperature calculation circuit further comprises a storage device, and wherein the frequency behavior with respect to temperature of the first and second crystals is stored in the storage device.

47. The downhole tool of claim 46, wherein frequency behavior with respect to temperature is stored prior to deployment downhole.

48. The downhole tool of claim 46, wherein the clock source further comprises a counter coupled to the oscillator, where the counter is adjusted using information from the storage device.

49. The downhole tool of claim 48, wherein the counter produces a clock signal having a predetermined period regardless of temperature.

50. The downhole tool of claim 44, further comprising a heat sink coupled to the crystals.

51. The downhole tool of claim 50, wherein the clock source further comprises a temperature maintenance device coupled to the heat sink, wherein the temperature maintenance maintains the crystals within a predetermined temperature range.

52. The downhole tool of claim 50, wherein the clock source further comprises a flask that contains the heat sink.

53. The downhole tool of claim 44, wherein the temperature calculation circuit further comprises an error detector adapted to determine the relationship between the frequencies associated with each crystal.

54. The downhole clock source of claim 53, wherein the error detector further comprises:

a first and a second counter each coupled to the oscillator, and wherein the first counter maintains a first count value proportional to the frequency of the first signal, and the second counter maintains a second count value proportional to the frequency of the second signal; and

a divider circuit coupled to the counters, and wherein the divider provides a ratio of the first counter value to the second counter value.

55. The downhole clock source of claim 54, wherein the ratio indicates the temperature of the crystals.

56. A method comprising determining an operating temperature of a first crystal based on a difference in frequency between a signal generated based on the first crystal and a signal generated based on a second crystal that is thermally coupled to the first crystal.

57. The method as defined in claim 56, further comprising adjusting a clock signal generated based on the first crystal for frequency variations of the first crystal related to the operating temperature.

58. The method as defined in claim 57, further comprising

generating a first signal based on a frequency of oscillation of the first crystal;

generating a second signal based on a frequency of oscillation of the second crystal; and

wherein the first signal's frequency is more stable, with respect to temperature, than the second signal's frequency.

59. The method of claim 58, further comprising:

maintaining a first count value proportional to the first signal's frequency;

maintaining a first count value proportional to the second signal's frequency;

calculating a ratio of the first and second count value, wherein the ratio of the first and second count values is proportional to the temperature of the crystals.

60. The method of claim 58, further comprising:

maintaining a count value;

incrementing the count value proportional to the first signal's frequency;

decrementing the count value proportional to the second signal's frequency; and

wherein the count value is proportional to the temperature of the crystals.

61. The method of claim 58, further comprising:

maintaining a count value;

decrementing the count value proportional to the first signal's frequency;

incrementing the count value proportional to the second signal's frequency; and

wherein the count value is proportional to the temperature of the crystals.

62. The method as defined in claim 58, further comprising:

mixing the first and second signal to produce a sum signal and a difference signal;

filtering out the sum signal;

analyzing, spectrally, the difference signal; and

wherein the spectral content of the difference signal is proportional to the temperature of the crystals.